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The Effects of Creative Problem Solving Training on Cognitive Processes in Managerial Problem Solving

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Abstract: The purpose of this study is to investigate the effect of Creative Problem Solving (CPS) training on managerial problem solving behaviors. The ill-defined nature of managerial problem solving process is modeled by a two-space four-stage search model. Twenty-two mangers solved a managerial case before they received 12 hours of CPS training (control group). Another 22 managers solved the case problem after the CPS training (experimental group). All managers were administered the *Torrance Test of Creative Thinking, Circle Test* before the CPS training. The results showed that after the CPS, managers in the experimental group improved in the number of inferences made in the problem space and the number of problem definitions linking the cognitive activities between problem space and solution space, compared to managers in the control group. Preliminary analysis of the relations between creative thinking ability and problem solving activities suggests that creative thinking is a sort of fluid human cognitive resource that can be directed to different components of problem solving process. The CPS has its effects on redirecting a manager's cognitive resources to bring out deeper understanding of the problem situation and more coordinated problem solving efforts.

Keywords: problem solving processes, managers, creative problem solving training.

Introduction

The generation of novel and potentially useful ideas concerning new products, services, manufacturing methods and administrative processes underlie the essence of organizational creativity (Amabile, 1988; Woodman, et al., 1993; Rickards, 1990, 1999). The Creativity of a firm often springs from individual manager and employee's novel ideas that form the starting point of innovative implementations in an organization. Creative thinking ability, as a source of novel ideas, is an innate human biological possibility that requires an adequate environment for its actualization. Thus, cultivation and nourishing of creative thinking and problem-solving skills are seen as a key for a firm's success in the age of technology and knowledge-based economy.

Creative techniques developed by professionals and scholars to promote and enrich production of knowledge base in innovation are numerous. For example, Higgins (1996) recognized seven creativity techniques, namely, brainstorming, storyboarding, mind mapping, excursion, checklists, morphological analysis and lotus blossom. In this study, rather than devising new techniques for creative ideas, we investigated the effects of creative problem solving (CPS), a program that has been widely used (e.g., Isaksen, 2000). The aims for the CPS are to train people to become more creative in both problem-finding and problem-solving when they encounter a vague situation. We postulate that in a knowledge-based economy characterized by "a realm of creative destruction" (Schumpeter, 1942) and "disruptive technological change" (Christensen, 1997.), rationale behind CPS training program may serve as an instructional scheme for organizational learning (Simon, 1991; Cohen and Levinthal, 1989), and the development of an organization's absorptive capacity (Cohen and Levinthal, 1990) and dynamic capabilities (Teece, Pisano, and Shuen, 1997).

CPS training is based on Osborn's (1963) idea of brainstorming, Four principles are stressed to increase the chance of emergence a new or novel idea: (1) criticism is ruled out, (2)

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quantity is wanted, the more ideas, the better, (3) free wheeling, the crazier the idea, the better, and (4) hitch-hiking, seeking improvement and combination of ideas. It has been developed into a six-step model of problem solving that includes problem finding, problem definition, solution finding, idea evaluation, implementation, and acceptance finding (e.g., Torrance, 1974; Torrance, Torrance, Williams, Horng & Crables, 1978; Parnes, 1988; Isaksen, 2000). Among these six steps, 3 steps require applications of divergent thinking ability, i.e., employing brainstorming technique to increase the quantity and novelty of ideas. The other three steps are pertaining to idea evaluation that requires applications of convergent thinking ability. Many versions of CPS have been proposed. Most of CPS models explicitly recognize the role of divergent and convergent thinking in the CPS process (Guilford 1967). Divergent thinking, the ability to produce a large number and assortment of unusual ideas, is considered to be the essence of the CPS process. Individuals must be adept at thinking divergently if they are to successfully expand the range of possible ideas from which to choose. A host of techniques designed to enhance divergent thinking has been proposed (Finke, Ward, and Smith 1992). Nevertheless, convergent thinking, the ability to converge on the best possible idea from a host of different ideas, also plays an important role in the CPS process. Individuals must be able to evaluate or judge the value of each idea if they are to effectively recognize the one that has potential for further development. All versions of CPS programs share a common structure of having time separately allocated for idea generation and idea evaluation so that a seemly irrelevant or bizarre idea may survive the premature evaluation and judgment.

Evidence has supported the effectiveness of the Osborn-Parnes CPS model on enhancing one's creative thinking ability (e.g., Basaduar, Graen & Green, 1982&Fontenot, 1992; Titus, 2000; Wang & Horng, 2002). More recently, it begins to have some supports for its effects on actual work outputs and problem-solving processes. For example, Fontenot (1992) employed CPS training to 62 american business managers. Thirty-four participants' post-CPS problem solving performance in solving a business case was compared to the pre-CPS problem solving performance of the other 28 managers. The results showed that eight hours of the CPS training significantly increased a participant's problem-solving performance measured by the fluency in data finding, and the fluency and flexibility in problem finding. Wang & Horng (2002) made an attempt to investigate the effects of CPS training on R&D performances with 106 R&D workers of a large manufactory company in Taiwan. Seventy-one of them volunteered to participate in the CPS training and were divided into three groups. Each group received 12 hours for CPS training and two follow-up training sessions over a one-year period in a time-series design. The results showed that participant's scores on fluency and flexibility of ideas were higher after the CPS training. In terms of R&D performance, participants' number of co-authored service projects increased significantly from pretest to posttest, whereas no such change was observed among the remaining 35 R&D workers who did not participate in the CPS. The purpose of this study is to examine whether or not the effect of CPS can be extended to cognitive processes in managerial problem solving.

Using computer as an analogy, human cognitive process in solving well-defined problems such as "tower of Hanoi" is modeled as a search in a problem space by Newell and Simon (1972) in their seminal book "Human problem solving." Given the information, there is a solution that can be judged as correct or incorrect in a well-defined problem such as mathematical proofs. However, there might be more than one path leading to the solution. A problem solver's task is to search and select a path that would lead to the correct solution. In less well-defined problems such as how to motivate an employee, the "correctness" of a solution is usually difficult or impossible to specify. Search in a single "knowledge space" becomes insufficient to account for the cognitive processes in problem solving. A two-space search model was later proposed to account for solving of more ill-defined inductive reasoning problems (Simon & Lea, 1974). Klahr & Dunbar's (1988) experiment provided empirical supports for the two-space model of problem solving. Their data further provide evidence for differential reliance of one space over the other among college students. In the study, college students were asked to discover the function of a toy robot's control key. From the concurrent verbal protocols collected from the participants, Klahr & Dunbar identified two distinct types of activities in the problem solving processes. One pertains to formulating possible hypotheses about the functions of the control key, the other pertains to actually trying the

key and see how it works. The former type of activities is said to occur in "hypothesis space" where many hypotheses are formed and searched. The latter type of activities is said to occur in "experiment space" where experiments are designed and carried out to obtain data to suggest possible patterns of behaviors which can be used to support the hypothesis previously formulated or to suggest a new one. Klahr and Dunbar labeled the participants who devoted relatively more time in formulating hypotheses before they actually tried to experiment with the control key "the theorist" and those who spent relatively more time experimenting with the control key without clear guidance of a hypothesis "experimenter." Their findings suggest that, relative to the experimenters, the theorists had a higher rate of discovering the answer to the control key. Klahr & Simon (1999) suggest that the two-space model can be expand to multiple spaces to account for various kinds of problem solving including the most complex and ill-defined scientific discovery process.

In this study, we postulate that an ill-defined problem differs from a well-defined one in that the problem is vague and unclear from the given information, thus render a direct search of solution impossible. A two-space, four-stage model is then necessary to capture a manager's cognitive processes during solving of an ill-defined problem (Wang & Horng, 1992). Based on Kintsch's model of comprehension (1998), the model posits that to solve an ill-defined managerial problem satisfactorily needs, most important of all, comprehension activities to transform the ill-defined problem into a better-defined one (*problem comprehension space*), then followed by a coordinated search between what is comprehended and a solution space where possible solutions for the defined problem can be tried out (*solution space*). The cognitive activities in each space are further divided into two categories: *data input* and *inferences* in the comprehension space and *solution finding* and *evaluation and/or justification* in the *solution space*. The rationale behind the four stages is that an ill-defined problem presents only an ambiguous, messy situation to a manager. Comprehension efforts must initially be directed to identification of critical features in the situation that might be relevant to comprehension of the core/hidden problem (*data input stage*). However, a vague situation suggests multitude of problems. Only when a core problem is clearly stated, efforts can then be directed toward finding possible solutions for it (*solution-finding stage*). Thus, after identification of the relevant information (symptoms) from the problem situation, identification of the core problem requires making inferences to bridge the gaps in those identified symptoms (*inference stage*). For a given problem, there might be more than one solution available. Therefore, it is necessary for a manager to carefully evaluate each option before a final solution can be proposed (*evaluation stage*). However, rather than deliberate evaluation of candidate solutions, some people may simply pick a solution randomly or choose the first one that comes to their mind, and then try to come up with various reasons to backup their solution. Thus, the fourth stage in the model can be either evaluation or justification of a solution, or both. The specific question we have raised in the study is whether or not CPS training will manifest its effects on any component of this problem-solving model.

Methods

Subjects

The subjects of this study were 44 managers of a small refining factory belonged to a refining and manufacturing research institute of a large petroleum company in Taiwan. The company operates two oil refineries that produce a topping capacity of 770,000 barrels of oil per day. The refining and manufacturing research institute was established mainly for the purpose of meeting the R&D needs of the two oil refineries. The small refining factory where our participants worked is similar to an experimental station of the refining and manufacturing research institute. It has about 300 production workers, 123 R&D workers, 110 R&D technical staffs, and 105 administrators. All participants in this study were managers of various ranks from various departments of the firm who responded to our training offer. They were randomly divided into two groups to receive the CPS training. The first group was treated as the experimental group and consisted of 23 managers (22 men and 1 woman; mean age = 48.66, SD = 7.05; tenure, M = 24.13, SD = 8.70).

The second one was treated as the control group and consisted of 21 male managers (age, M = 51.86, SD = 7.36; tenure, M = 25.80, SD = 8.48). There are no significant differences between the two groups in terms of age and tenure. All managers had a minimum of college level education.

Experimental Design

A pretest-posttest quasi-experimental design with nonequivalent control group was used in the present study because to the difficulty of doing true experimental manipulation in a work setting. Twenty-two managers in the control group solved a managerial case before they received 12 hours of CPS training. The other 22 managers in the experimental group solved the case problem after they received the CPS training. All managers worked individually in a laboratory and were asked to "think aloud" while solving the case problem (Ericsson and Simon, 1993). Each of them first practiced the think-aloud method with a two-digit multiplication task and then solved the managerial task. The experimenter sat behind the manager quietly and tape-recorded his/her verbal protocols. No feedback was given during the problem solving session. The problem solving task took approximately one hour to finish. The experimental layout was depicted in Figure 1. Participants' measures of creative thinking ability were collected before the CPS training.

Day	1	2	3	4	5	6	7	8
EG	CPS	CPS	PM	PM				
CG					PM	PM	CPS	CPS

Legents: EG, experimental group; CG, control group; CPS, Creative Problem solving training; PM, case problem.

Fig. 1. The time flow of the quasi-experimental design with two equivalent groups of managers in 8-day period.

We examined the equivalence of the two groups of managers in terms of age, tenure, creative thinking abilities measured by *Torrance Circle Test* (1974), and cognitive style measured by *Myers-Brigg's Type Indicator* (Myers, et al., 1998). The results showed that there was no difference between the two groups in all measures (t values ranged from -0.05 to -1.36).

CPS Training Procedure

The CPS training given to the R&D workers was designed according to an instructional model developed by Torrance, et al. (1978). When a problem situation is perceived, the problem solving process is broken down into 6 steps, namely: 1) identifying sub-problems, 2) identifying and stating the core problem, 3) producing alternative solutions, 4) evaluating solutions, 5) planning the implementation of the best solution, and 6) selling the final solution. At each step, an individual's problem solving effort is set either to brainstorm as many alternative ideas as possible (step 1, 3, 5), or to evaluate and choose the best idea (step 2, 4, 6). The problems that were used in the CPS training were mostly obtained from the participants and were general issues unrelated to their work such as child abuse and deterioration of the world ecology.

The 12-hour CPS training program was carried out in two consecutive days. At the very beginning, prior to the CPS training, a short course covering the following topics were given to the participants: (a) the nature of creativity and the factors affecting it, (b) brainstorming technique and practices, and (c) an overview of the CPS training program and its underlying mechanisms. Then, participants were randomly divided into four groups in which they worked together during the 12-hour training. At the beginning of the CPS training, a problem situation was described and the group members had to solve it collaboratively and step by step according to the of CPS program, namely, finding alternative problems, identifying the problem, brainstorming the possible solutions, evaluating the solutions, implementing the best solution, and selling the final solution.

However, due to time constraint and the redundancy of the procedure, the last two steps, implementing the best solution and selling the final solution, were not practiced, but only explained. There were two graduate students who were familiar with the CPS to provide assistance to the participants.

Problem solving task

After the CPS training participants had to solve a case problem. The case itself describes the financial statements and the human resource management issues of a petroleum manufacturing company. The managers had to identify the company's problems and propose solutions for them.

Measures of problem solving processes

Participant's problem solving protocols were transcribed, preserving its sequential order. Each sentence was classified exclusively as either an element in the problem comprehension space or an element in the solution space. Statements that were classified into problem space were constrained to those verbalized prior to any statement related to solution finding or solution evaluation. Variables measured in the problem comprehension space include:

1. *The number of data used*, refers to the number of facts a participant taken directly from what is given in the case description.

2. *The number of inferences made*, refers to the number of new information generated by a participant from the case.

3. *The total number of responses in problem space*, refers to the sum of the above two variables.

Verbal statement that was not included into the problem space is classified as belonging to the solution space. Variables measured in the solution space include:

1. *The number of solutions* refers to the number of solutions proposed by a participant in order to solve the problem he/she identified.

2. *The number of after-solution activities*, refers to the number of justification or evaluation responses a participant made after a solution was proposed:

Justification response. The number of the data a manager gathered from the case text to support his solution.

Evaluation response. The number of the inferences a manager made after a solution was made in order to evaluate the efficiency of the solution.

3. *The total number of responses in solution space*, refers to the sum of the above three variables.

Problem Solving Strategy

When dealing with ill-defined problems, one's solution selection is highly contingent on how one defines the problem. Managers' problem solving strategy therefore must also be examined in terms of how they connect or integrate search efforts between the two spaces. A higher degree of top-down or schema-driven strategy, in contrast to bottom-up or data-driven strategy, is used if search in the solution space is guided by the result of search in the problem comprehension space. Thus, we expected to see a higher degree of linkage between two spaces if more top-down problem solving strategy was observed. The number of problem definitions was used in the present study as an index of the degree of top-down strategy. It refers to the number of inferences generated in the problem space that directly led to ansolution idea in solution space.

Table 1 gives an example of protocol analysis and scoring. Inter-rater and intra-rater scoring reliability was estimated from three independent scorers. Inter-rater reliability of all the variables ranged from 0.86 to 1.0. Intra-rater reliability ranged from 0.81 to 1.0.

Table 1

A sample of protocol scoring

Portion of manager A's verbal protocol:

"…100 salaried employees… 500 waged operators…number of turnovers due to avoidable causes were 15…it suggests that the company has too many employees…and turnover rate too high…seems there is room for improvement in human resource management…should re-evaluate employee's occupational capabilities…or, making changes in work design…this should be able to improve the company's performance…."

Scoring:

Problem	Space		Solution	Space	
Data Input	Inference	Problem Definition	Solution	Justification	Evaluation
1. 100 salaried workers (d1)					
2. 500 waged operators (d2)	4. Too many employees (i1)				
3. 15 persons left the comp -any due to avoidable causes (d3)	5. Turn over rate too high (i2)	6. There is a human resource management problem (pd1)	7. Should Re-evaluate employee's occupational capabilities (s1)		
			8. Job re- design (s2)		9. Should lead to improved organization-al performa - nces (e1)
Data = 3	Inference = 2	Definition = 1	Solution = 2		Evaluation = 1

Measurement of Creative Thinking Ability

A creativity measure, *The Circle Test*, was included into the study as a check of participant's initial level of creativity. It was an abbreviated form of the *Torrance Test of Creative Thinking, Figural Form* (Torrance, 1974). The time limit for the test is 10 minutes. The test-retest reliability coefficients of the Line Test with Taiwanese sample range from .51 to .81. The inter-rater reliability for the present study ranged from .97 to .99. Four measures of creative thinking ability—fluency flexibility, originality, and elaboration—can be obtained from the test. Their definitions are described below.

1. *Fluency* refers to the number of different ideas one generated in 10 minutes.

2. *Flexibility* refers to the number of different conceptual categories into which the total responses can be classified.

3. *Originality* refers to the rarity or uniqueness of an idea determined by its statistical infrequency. One point is awarded to a response that occurred in less than 1% of the norm, zero otherwise.

4. *Elaboration* refers to the number of details one adds to an idea to make it more complete or interesting.

Results

Validation of the two-Space model

A total of 8 variables were derived from 44 managers' verbal protocols to capture their cognitive processes while solving the managerial case problem. These variables were the factor analyzed to examine its fit to the two-space model we proposed to account for the problem solving processes. The results show that 88% of the total variance in participants' problem solving behaviors can be explained by four factors. The varimax rotated factor structure was listed in Table 2. The first factor is labeled "solution space" which is constituted by three variables, namely, total number of responses in solution space, number of evaluative responses, and number of solutions. This factor alone explains 43.80% of the total variance of participants' problem solving behaviors. The second factor is composed of the total number of responses in problem space and the number of data used, and is thus labeled "problem space." This factor accounts for 18.74% of the total variance of participants' problem solving behaviors. The third factor explains 16.34% of the total variance. It is constituted by the number of problem definitions and inferences, and thus labeled "problem definition." The fourth factor that accounts for 9.25% of the total variance is composed of justification responses.

Table 2

Factor Structure of Manager's Problem Solving Protocols

Factor / Variable	1	2	3	4	h^2
Solution Space	***0.93***	-0.22	0.13	0.26	0.99
Evaluation	***0.89***	-0.09	0.09	-0.18	0.84
Solution	***0.87***	-0.22	0.18	0.21	0.88
Comprehension Space	-0.18	***0.98***	0.07	-0.06	1.00
Data	-0.20	***0.94***	-0.24	-0.06	0.99
Inference	0.10	-0.02	***0.94***	0.01	0.90
Problem Definition	0.26	-0.15	***0.58***	-0.40	0.58
Justification	0.17	-0.12	-0.10	***0.91***	0.88
% Variance Explained	43.80	18.74	16.34	9.25	88.13

Although the variables did not fall exactly into the same grouping as we proposed, the results of factor analysis provide a certain degree of preliminary supports to the adequacy of the two-space model of problem solving.

Problem solving behaviors in the two spaces

The total number of responses in the two spaces. The experimental and the control group's mean numbers of responses in the two spaces are listed in Table 3. The result of t-test showed that the two groups did not differ significantly in the total number of verbal responses ($t = -0.68$, $df = 36$) produced during problem solving. That means managers who solved the managerial case after the CPS training did not in general talk more than those who completed the case problem without the CPS training. However, Table 3 shows that the total number of responses in problem space and solution space is about 5 (83%) to 1 (17%) in ratio. It clearly indicates that solving ill-defined managerial problems requires more conceptualization and analysis of the problem than decision regarding a solution.

Table 3

Mean Number of Responses and Response Distribution in the Two Spaces (%), and t-Values of the Two Groups

Group / Variables	Experimental (n = 21)			Control (n = 17)				
	M	*SD*	%	*M*	*SD*	%	***t***	
Problem Space								
Data	16.10	16.78	***50.92***	18.82	15.93	***66.24***	0.51	
Inference	10.00	4.98	***31.63***	4.76	3.93	***16.75***	-3.53	**
$Total_{problem}$	26.10	16.03	***82.54***	23.59	15.58	***83.03***	-0.49	
Solution Space								
Solution	4.29	4.62	***13.57***	3.24	3.58	***11.40***	-0.77	
Justification	0.05	0.22	***0.16***	0.82	1.29	***2.89***	2.46	*
Evaluation	1.29	1.68	***4.07***	0.76	1.39	***2.68***	-1.03	
$Total_{solution}$	5.62	5.79	***17.72***	4.82	5.41	***16.97***	-0.43	
$Sum_{two\ spaces}$	31.71	15.67		28.41	13.85		-0.68	
Between spaces								
$Definition_{problem}$	2.24	2.12		0.65	1.00		-3.05	**

* $p < 0.05$, ** $p < 0.01$

Problem comprehension space. In order to examine the effect of CPS training on manager's problem solving behavior, we compared the differences between means (Table 3) of the experimental group and the control group using t-test. The results show that CPS training indeed can encourage manager's inference behaviors during problem solving processes ($t = -3.53$, $df = 36$, $p < 0.01$). But, the difference between the two groups was not significant either in terms of the number of data ($t = 0.51$, $df = 36$) they extracted from the problem case, or the number of total responses in the problem comprehension space ($t = 0.51$, $df = 36$). Clearly, what the experimental group gained from the CPS training is not in terms of the total number of responses they produced in problem comprehension, but a differential emphasis on the inferences they could made from the data embedded in the problem situation, rather than merely on the surface information explicitly given in the text.

Solution Space. All in all, the experimental group and the control one did not differ significantly in terms of the total number of responses in the solution space. Further we will examine separately the differences between the two groups in terms of the two variables in the solution space: the number of solutions a manager had come up and the number of justifications or evaluative responses after a solution was chosen. Although managers who solved the case problem after the CPS training tended to raise more solutions for the problem case ($M = 4.29$, $SD = 4.62$) than the control managers who completed the case problem without CPS training ($M = 3.24$, $SD = 3.58$), the difference was not significant statistically. Nevertheless, the difference between the two groups in terms of the number of justifications they gave after a solution selection was significant ($t = 2.46$, $df = 36$, $p < 0.05$). The experimental group gave less justifications after a solution selection ($M = 0.05$, $SD = 0.22$) than the control group ($M = 0.82$, $SD = 1.29$). No significant difference was found in terms of the number of evaluative response after the solution selection ($t = -1.03$, $df = 36$), although the experimental group seemed to engage in slightly more evaluative activities after a solution selection ($M = 1.29$, $SD = 1.68$) than the control group ($M = 0.76$, $SD = 1.39$). Generally speaking, managers who solved the case problem without CPS training tended to engage more in justificatory activities that are post hoc rationales for a solution that was proposed without clear deliberation.

Problem Solving Strategy

Manager's problem solving strategy was inferred from the degree of connection between the problem solving efforts in the two spaces. A higher degree of connection between the two spaces suggests a higher degree of schema-driven strategy. Data showed that there was a significant difference in the number of problem definitions ($t = -3.05$, $df = 36$, $p < 0.05$) between the two groups. Managers who solved the problem-solving task after the CPS training made more efforts to integrate the problem solving activities between the two spaces (Table 3) compared to managers who solved it without CPS training. In other words, they were more inclined to conceptualize/define problem first and then select solutions accordingly.

Relations between Problem Solving and Creative Thinking Abilities

The above analysis shows that CPS training is effective in enhancing certain cognitive activities in solving ill-defined managerial case problem. Recall that the design of the CPS procedure incorporates two major types of thinking processes, namely, divergent thinking and convergent thinking. Creative thinking ability measured by Torrance Circle test primarily measures one's divergent thinking in terms of fluency, flexibility, originality and elaboration. Problem solving requires not only creative, innovative ideas, but also the ability to integrate or transform the ideas to fit the task requirements of the problem situation. It would be interesting and informative if we can get a glimpse of how creative thinking abilities relate to the problem solving activities in the two spaces. Table 4 lists the Pearson correlations between creative thinking measures and problem solving variables.

Before CPS training. Unfortunately, only 9 managers in the control group completed the Torrance Circle Test. Although the statistics is severely constrained by the small sample size, Table 4 shows that prior to CPS training, one's creative thinking ability was related positively to the number of data considered in the problem comprehension space ($r's > .53$), but negatively with both the number of solutions proposed ($-.55 > r > -.20$) and the amount of justification activities ($r's > -.41$) in the solution space. The correlations between creative thinking measures and the number of problem definitions ($r's > -.41$) and evaluations ($-.35 > r > .00$), although insignificant, were also negative. This pattern of correlations suggests two things. First, these managers' creative/imaginative activities were confined to search for information explicitly mentioned in the text during problem comprehension. As a consequence, their creativity did not help them go beyond what was given to bring out the core problem implicit in the case problem. Second, if we grant that problem definition and evaluative activities require convergent thinking, it is evident that creative thinking ability, measured by divergent thinking test alone, is not sufficient for problem solving. Thus, one's ability to free alternating between convergent thinking and divergent thinking in productive thoughts merits our paying more attention to it in theories and practices of creativity.

After CPS. Fortunately, we were able to gather 19 of experimental group's creative thinking ability measures prior to the CPS training. Due to the small sample size, only the negative correlations between the evaluative activity in the solution space and the fluency and originality measure of creativity were statistically significant. Interestingly, the patterns of correlations between creative thinking measures and problem solving variables are rather similar before and after the CPS training with two very notable exceptions. First, there was a reverse in the direction of correlations between creativity measures and the two variables, data input and inferences made, of problem comprehension stage. Prior to CPS training, creativity was associated with greater use of textual information, but it became correlated to a greater number of the inferences after the training ($.12 > r > .24$). Second, the magnitude of negative correlation between creative thinking and problem definition ($-.22 > r > -.34$), and the number of solutions proposed ($-.12 > r > -.19$) seem to diminish considerably after CPS training. It suggests that creativity is a sort of fluid cognitive resource that can be directed to different dimensions of a task. In the current case, it seems that with CPS, managers have learned to distribute their creative resources more to problem comprehension and definition activities. How to apply our creativity in a more meaningful or productive way so that it is conducive to problem solving and innovation is then an important issue in education and

training of managers. CPS training deliberately divides the problem solving activities into idea generation stage and idea evaluation stage. Its emphasis on the alternation of divergent thinking and convergent thinking components during problem solving processes may help managers to become more sophisticated in distributing their creative efforts to various components of problem comprehension and solution finding. However, the persistent negative correlations between creativity and evaluative activities before and after CPS training suggest that our CPS training procedure is relatively less effective on improving one's convergent thinking ability. How to improve CPS training procedure to accommodate the need of convergent thinking in problem solving is a challenge for future studies.

Table 4

Correlations between Problem Solving Variables and Creative Thinking Measures Before and After CPS Training

		Before CPS		After CPS	
		(n = 9)		(n = 19)	
Data used	Fluency		0.72*	-	0.14
	Flexibility		0.72*	-	0.23
	Originality		0.53	-	0.17
	Elaboration		0.56	-	0.02
Inference	Fluency	-	0.14		0.23
	Flexibility		0.00		0.24
	Originality	-	0.01		0.12
	Elaboration	-	0.24		0.28
Problem	Fluency	-	0.51	-	0.29
Definition	Flexibility	-	0.42	-	0.34
	Originality	-	0.48	-	0.25
	Elaboration	-	0.41	-	0.22
No. of	Fluency	-	0.55	-	0.16
Solution	Flexibility	-	0.53	-	0.17
	Originality	-	0.45	-	0.19
	Elaboration	-	0.20	-	0.12
Evaluation	Fluency	-	0.35	-	0.47*
	Flexibility	-	0.35	-	0.15
	Originality	-	0.29	-	0.54*
	Elaboration		0.00	-	0.24
Justification	Fluency	-	0.69*	-	0.07
	Flexibility	-	0.68*	-	0.01
	Originality	-	0.47		0.08
	Elaboration	-	0.41	-	0.02

* $p < 0.05$, ** $p < 0.01$

Discussions and Conclusions

Creative problem solving involves search through theoretical paradigms (problem space) and solutions and experimental routines (solution space). It is a mechanism by which an individual goes beyond his mind set and institutional conformity to create an atmosphere for creative breakthrough. In this study we investigated the effect of creative problem solving training on a man-

ager's cognitive processes in solving of an ill-defined problem. CPS is a training program designed to facilitate one's chance of discovering a creative problem or solutions to a problem. The effects of CPS training on creativity have been largely confirmed (e.g., Fontenot, 1992), and the effect of CPS on real-world problems solving has beginning to gain empirical supports. Upon analysis, the key components of the CPS are to identify the possible problems from a mass situation, define the core problem behind the mess, then produce alternative routines that might solve the problem, evaluate these alternatives and come out with a final solution plan. These components are closely related to the cognitive stages in problem solving (e.g., Dewey, 1933; Newell and Simon, 1972; Klahr & Simon, 1999). Therefore we proposed a two-space four-stage model to account for the observed behaviors among our participating managers. The factor structure extracted from our participating manager's verbal protocols fits the model to a large extent. These four factors, namely, problem finding, problem definition, solution finding, and evaluation or justification of the solutions, provide us with a framework to better capture cognitive processes involving into ill-defined managerial problems solving. As Table 3 illustrates that the ill-defined nature of the task was indeed reflected from the large amount of efforts our participants allotted to the problem comprehension space.

The results of our study show that with 12 hours of CPS training, managers have increased in their tendency to make inferences from the information given. Also, they tended to employ a model driven strategy in solving of a managerial case, namely, they were better able to integrate the activities from the problem space to the solution one.

In spite of the fact that the number of available data were limited and thus any of derived conclusions is only speculative, we also observed that a manager's creative thinking abilities may be associated positively with his problem solving process variables, namely, utilization of raw data, but negatively with problem definition and evaluation or justification of a solution. It suggests that creative managers tend to be more sensitive to data in the context. However, this sensitivity may not be sufficient for the effective problem solving because divergent thinking ability is negatively correlated with ability to define a problem and evaluate a solution, which may be critically contingent on one's convergent thinking ability. The effects of CPS seem to be a remedy. The diminished negative correlations between measures of creative thinking ability and problem definition provide some weak and indirect supports. Even though our study was constrained by its quasi-experimental design nature and a single firm setting, it still sheds some light on the managerial problem solving processes in a real world context and we are sure that the effects of CPS in modifying these process variables deserve more attention of the management people.

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